

**ECONOMY AND ENVIRONMENT PROGRAM  
FOR SOUTHEAST ASIA**

**Pricing for Groundwater Use of Industries in Metro  
Manila, Philippines**

**Maria Corazon M. Ebarvia**

**EEPSEA RESEARCH REPORT SERIES**

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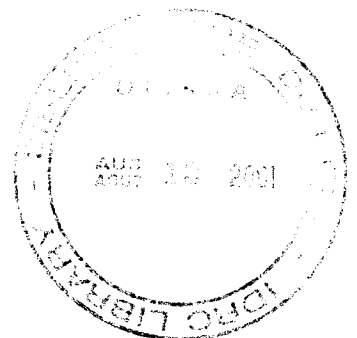


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## ABSTRACT

The rapid growth, urbanisation and migration in Metro Manila has resulted in increasing water demand which has outpaced the capacity of the water agency or MWSS to expand supply. Unserved sectors resorted to the construction of wells while others resorted to tapping illegal connections to MWSS pipes. For the period 1990-96, groundwater level declined at an estimated rate of 6-12m per year. The groundwater resources are, therefore, being threatened by salt water intrusion, contamination, and eventual depletion. This implies that current extraction and utilisation of a unit of those resources involve an opportunity cost which is the value that can be gained in the future. An efficient policy is one that equates price of any commodity (resource) or service with the cost of producing an additional unit of it, or the *marginal cost*. Ideally, the price charged for water should equal not only the economic cost, but should also account for environmental costs involved from its production and disposal.

This study involves the estimation of the marginal opportunity cost (MOC) of meeting the water demand requirements of the industrial sector. The MOC has three components: marginal private or direct cost (MPC), the marginal user cost (MUC) or the scarcity premium, and the marginal external costs (MEC). The water tariffs are generally based on the average cost pricing, rather than on marginal cost pricing, and opportunity costs are not properly accounted for. Moreover, about 82% of the industries have installed their own deep wells therefore, they have self-supplied water and are not subjected to water tariffs, but only to a limited form of annual charges. The costs of installing and operating a well and pump have been the principal regulators of groundwater use. As a result, excessive quantities of water are used, and excessive pollution is produced, affecting in turn the availability of water for others and for future use. Setting the socially optimum price equal to the MOC would highlight the relationship between the depletion of the resource and impacts on the economy over time.

Different scenarios were developed for the MOC estimation of groundwater and MWSS water. The combined use of groundwater and MWSS is the least-cost alternative. This would require that withdrawal from the aquifer be regulated, and that MWSS will develop alternative sources and improve the distribution network and water delivery services. For regulation of groundwater extraction, all groundwater users must secure permits, install meters, and pay the corresponding cost (MOC for fully groundwater-supplied users). The regulating agency should also start implementing a monitoring network. The combination of pricing and structural reforms can lead to the optimal use of a resource threatened by eventual depletion. Another instrument that should also be considered is a separate charge on wastewater and effluent discharges. Imposing an effluent charge would also serve as incentive for firms to treat wastes before discharging to a receiving water body or to recycle water and minimise both water consumption and total wastewater flows. Thus, the use of the demand management approach and the proper pricing of the resource, in conjunction with the standard engineering and supply-side approach to the water problem, could lead to a more optimal utilisation and improved allocation of this resource over time.

# **PRICING FOR GROUNDWATER USE OF INDUSTRIES IN METRO MANILA, PHILIPPINES**

**Maria Corazon M. Ebarvia**

## **1.0 INTRODUCTION**

### **1.1 Rationale and Background**

The rapid growth, urbanisation and migration in Metro Manila has increased water demand which has outpaced the capacity of the water agency, the Metropolitan Waterworks and Sewerage System (MWSS), to expand supply. Unserved sectors have resorted to well construction while others have resorted to tapping illegal connections to MWSS pipes. Considering that only 65% of the population in the study area is served by the MWSS, and groundwater accounts for only 3% of the MWSS water supply sources, there is a need to focus attention on the private extraction and utilisation of groundwater resources in Metro Manila.

Average annual groundwater withdrawal for the period 1982-1990 was estimated to be about 235.01 million cubic meters (MCM) while the average annual recharge for the same period was only 206.16 MCM (IDRC-UP-NHRC, 1993). Thus, the rate of mining during this period is 28.84 MCM, resulting in the lowering of the water table by 2.5 meters annually. For the period 1990-96, groundwater level declined at an estimated rate of 6-12m per year. Groundwater resources are, therefore, being threatened by salt water intrusion, contamination, and eventual depletion. This implies that current extraction and utilisation of a unit of those resources involve an opportunity cost which is the value that can be gained in the future. Economists would define over-exploitation as any pumping rate in excess of that which yields the maximum present value of net benefits (Young, 1991). This approach would call for the utilisation of groundwater stocks if demand so requires, but scale back extraction rates as the aquifer becomes depleted and the "full costs" become higher.

The main coverage of the study is the National Capital Region or Metro Manila which consists of eight cities and nine municipalities. The jurisdiction of MWSS includes the National Capital Region (NCR), Rizal province, and parts of Cavite province in Region IV. Its land area is about 2,125 sq. km., with a population of 9.37 million. The NCR and Region IV are the most urbanised and economically developed areas in the country. Aside from being the seat of the National Government, the NCR accounts for 30 percent of the country's Gross Domestic Product.

### **1.2 Objectives of the Study**

This study aims to direct attention to the water use of industries and to apply the marginal opportunity cost pricing in deriving the price that should be charged to the sector. A survey conducted in 1990 showed that about 82% of the industries have installed their own deepwells (JICA-MWSS, 1992). A recent survey done for this study



obtained the same percentage of industries with deepwells. The basic concern is the estimation of the marginal opportunity cost (MOC) involved in meeting the water demand requirements of the industrial sector. Because of the divergence between private and social costs of groundwater use, the unregulated market cannot be relied upon to induce extraction at the optimal level. Due to the non-exclusiveness property of the resource, such an outcome is unlikely.

According to standard economic theory, the efficient use of water resources takes place at that level of water use where the demand curve for water intersects the supply curve. At the point of intersection, one can determine the correct quantity to use and the price at this level. Information on either price or quantity can be used as tools to arrive at the efficient resource allocation. An efficient policy is one that equates price of any commodity (resource) or service with the cost of producing an additional unit of it, or the *marginal cost*. Ideally, the price charged for water should equal not only economic cost, but should also account for environmental costs of its production and disposal. As a concept, calculating for MOC consists of finding the true cost of an action that depletes a unit of renewable or quasi-renewable resource in a way that inhibits the natural regenerative process. That is, the resource is managed in a non-sustainable way (Pearce and Markandya, 1989). The MOC has three components. These are the marginal private or direct cost (MPC), the marginal user cost (MUC) or the scarcity premium, and the marginal external costs (MEC).

The water demand of industrial establishments depends on the cost of obtaining a particular source of water, the production volume or output, and the type of industry. The future demand requirements are estimated by considering the projected growth of this sector, the plans of existing firms and the entry of new firms. Based on these demand requirements, the private and social costs involved in using water from MWSS, from groundwater or private deepwells and other sources are each estimated. The firm is assumed to make its water choice selection on the basis of the attributes of the water sources available. The decision will depend on the corresponding price, quantity and quality of water that minimises its production cost. The MOC of MWSS is compared to the current water tariff being charged by this agency. It is likewise compared to the MOC of groundwater in order to evaluate the least-cost program.

### **1.3 Significance of the Study**

Given the common property nature of environmental services from groundwater use and waste disposal services, firms are likely to ignore social costs unless reflected in effluent taxes or extraction taxes which the firms must pay. Efficient pricing requires that true marginal costs be used, including opportunity costs and externalities involved in the use of this resource. Water tariffs are generally based on average cost pricing, rather than on marginal cost pricing, and opportunity costs are not properly accounted. Moreover, industries have self-supplied water. Therefore, they are not subjected to water tariffs, but to a limited form of annual charges. The costs of installing and operating a well and pump have been the principal regulators of groundwater use. As a result, excessive quantities of water are used, and excessive pollution is produced. In turn, these affect water availability for others and for future use. Setting the socially optimum

price equal to the marginal opportunity cost (MOC) would highlight the relationship between the depletion of the resource and impacts on the economy over time.

For the industrial sector in Metro Manila, about 82% of its water supply comes from groundwater. It is essential that the relevant and applicable combination of incentives to achieve efficiency in the industrial use of groundwater resources be found. Incentive systems are not costless since they involve regulation, monitoring and enforcement. Conservation or switching to water-saving technologies, likewise, entails investment costs. The main policy instrument considered in this study is the increase in the price of water used/purchased to reflect the marginal opportunity cost. Policy simulations were done to analyse the impact of implementing MOC pricing on the demand for water by industries, and on the final price of the industries' output. The other policies which could be looked into are the expansion of the MWSS distribution system or its privatisation, the regulation of pumpage rates in areas already contaminated by salt water, zoning of water-intensive industries to places with relatively abundant water supply, implementation of effluent and wastewater charges, and fiscal incentives.

#### **1.4 Review of Related Studies**

To choose the most appropriate policy, the water sector was divided into supply-side and demand-side components. The traditional approach is the supply-side which is oriented towards structure development, and focused on the provision of water supply and related services. Water was traditionally abundant, and development of water resources relatively easy. Large hierarchical organisations were created, combining technical and engineering expertise for water control, storage, conveyance, and delivery. Due to variability of water supply in terms of time, space, location and quality, storage reservoirs were built. Realities, however, have changed, and uncertainty and variability of supply necessitated making better use of existing supplies as an alternative to new construction, yielding uncertain water increments (Hirschleifer and Milliman 1967). Construction of large reservoirs also resulted in increasing environmental costs and the quality of available supplies deteriorated due to increasing pollution and siltation. These problems further widened the gap between demand and supply.

Due to both technical and financial difficulties involved, the focus of policymakers has shifted to non-structural approaches which include demand management, education and research. Many demand-side policies attempt to coordinate water use through market-based instruments such as instituting property rights, and incentive structures like charges or prices. The two factors that significantly influence the form of water institutions are the relative scarcity of water, and the transaction costs required to establish and enforce water rights (FAO 1993).

Several World Bank studies discuss the extent of water resource and water-related environmental problems in Asia. They describe various strategies to environmentally- and socially-sound water resource management, particularly the relevance of considering pricing and other demand management options (World Bank, 1993; Garn 1993). Gibbons (1986) documents the various studies and approaches to the estimation of the economic value of water to users in the different sectors. Bhatia,



Cestti and Winpenny (1993) provided a compendium of cases where demand management has improved the use of water, and identified the ingredients of success in each case. Their study also documents policy measures that encourage both economically efficient and equitable use of water resources in various ecological, developmental, and institutional settings.

There are studies which show that the use of pricing as an instrument for affecting demand and use of water is more effective for industrial users than for domestic users. Industrial and agricultural price elasticities tend to be higher than for domestic consumption, thus, a given price increase will tend to provide a greater incentive to former users to conserve water by introducing water saving practices and technologies (Garn 1993). Furthermore, because wastewater is a direct consequence of water use, it is also possible to curb the demand for water by curbing the ability to discharge wastewater. The problem of water pollution can, likewise, be addressed to a certain extent by regulating uncontrolled wastewater discharges through the imposition of proper effluent charges or by providing incentives for wastewater disposal and recycling. In a study done in India, the water conserved by the industrial sector through the imposition of proper water prices and effluent charges enabled the government to increase service to the unserved urban population (Bhatia, *et al.* 1992). Managing both the water consumed and discharged provides an important economic and environmental linkage. Thus, the use of the demand management approach and the proper pricing of the resource, in conjunction with the standard engineering and supply-side approach to the water problem, could lead to more optimal utilisation and improved allocation of this resource over time and across sectors.

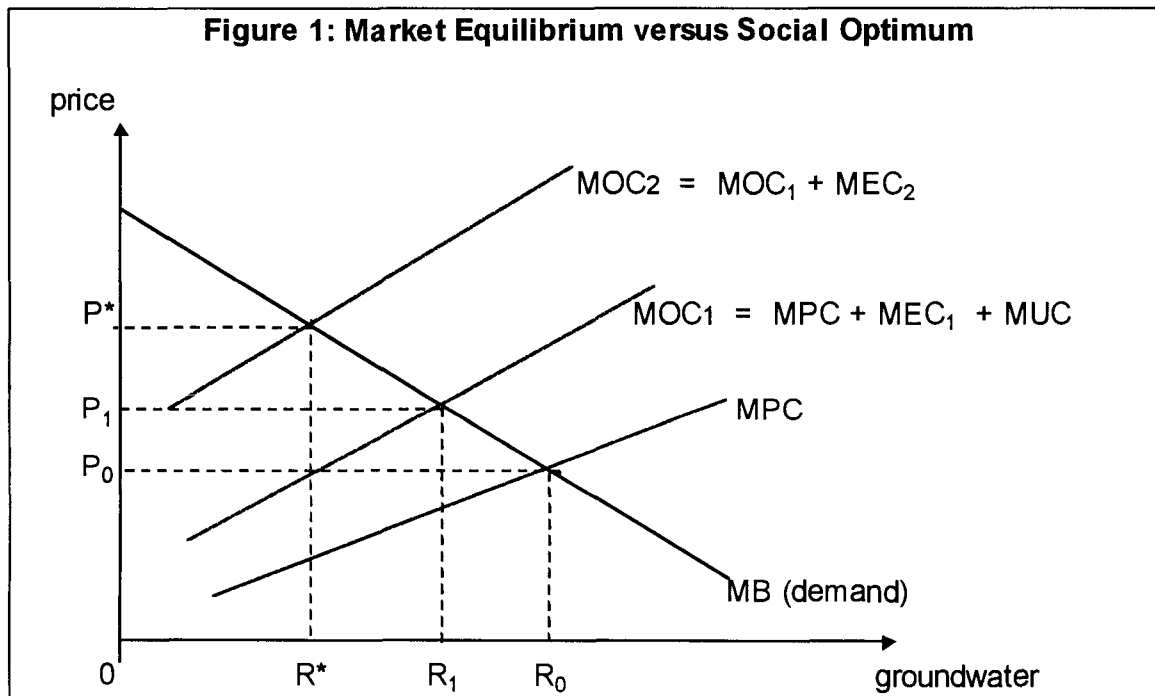
Most of the studies on urban water management problems in Metro Manila focused on the water supply services of the MWSS. However, not enough attention is given to private supply and use, particularly for groundwater resources. There are studies pertaining to the area's hydrogeology, problems related to groundwater extraction, and water resources modeling on the conjunctive use of surface and groundwater. They are directed, however, towards the MWSS management problems, and aimed towards increasing the water supply to meet the escalating demand for water -- the typical engineering solution to the water problem. With regards to studies on demand management, in particular pricing, Munasinghe (1990) estimated the marginal cost of groundwater withdrawal by computing for the average incremental cost of MWSS supply. It should be noted, however, that MWSS use of groundwater is only about 9% of total withdrawal from the aquifer.

In this study, the framework for pricing follows Warford's (1994) approach to the pricing of water resources, and this involves estimating the marginal direct or private cost, marginal user cost and the marginal external cost of using this resource. The marginal private cost includes the costs of production, such as investment and operating costs which are a function of water consumption. The marginal user cost or the depletion premium involves estimating the present value of the cost of replacing the resource when it becomes depleted at some future period. The marginal external costs refer to the costs of environmental damage caused by over-extraction of groundwater

(e.g., drying up of wells in the area and saltwater intrusion), by the discharge of wastewater, and by dam or reservoir projects.

Figure 1 shows a market equilibrium characterized by a situation in which the externality is not priced. The market is governed by the relationship of the industrial sector's demand for groundwater, given by the marginal benefit curve MB. The MPC is the marginal private cost, and the MOCs are the marginal opportunity costs or the social costs associated with this production.

In setting the quantity level that will be produced, the market will be guided by the marginal cost curve that reflects the private marginal cost of groundwater extraction, leading to an extraction level given by  $R_0$ . The socially optimal level of groundwater extraction, however, is at  $R_1$  or  $R^*$ . The prevailing market price for water is given by  $P_0$ . The gap  $R^*R_0$  represents a market failure. Thus, the willingness to pay of groundwater users does not incorporate an allowance which will compensate for the external effects of its usage. To achieve efficient pricing, what is required is a charge that will raise the price of water to the amount  $P_1$  or  $P^*$ . Alternatively, this can be achieved by constraining the quantity of groundwater that can be extracted to  $R_1$ , where market forces will drive the water price up to the point  $P_1$ . The price level  $P_1$  considers the marginal opportunity cost associated with the extraction or consumption of groundwater while at price  $P^*$ , the social cost associated with discharges are also incorporated. The optimal charge for groundwater extraction is  $P_0P_1$  while a pollution charge can be set equal to  $P_1P^*$ .



The choice between taxes and quantity restrictions is not simply a question of administrative feasibility, although focusing on either prices or quantities can achieve the desired results. In the case of quantity restrictions, the revenues accruing from the higher price of water will go to the companies producing water, whereas under a tax scheme, the charges will go to the government.

## 2.0 WATER DEMAND AND SUPPLY CONDITIONS IN METRO MANILA

### 2.1 Supply Conditions

#### 2.1.1 Water Resources in the MWSS Service Area

Hydrologically, the area is located within the Pasig-Laguna de Bay river basin. The MWSS' water sources consist of surface water (97%) and groundwater (3%). The main source is the Angat River whose catchment (Bulacan province) does not form part of the MWSS service area. There are two new sources being developed. One is the Umiray River that drains part of Quezon province. The other is Laguna de Bay that drains the provinces of Laguna and Rizal, and parts of the National Capital Region (NCR) and Batangas. The following table shows the sources of MWSS of raw water:

**Table 1. Sources of Raw Water**

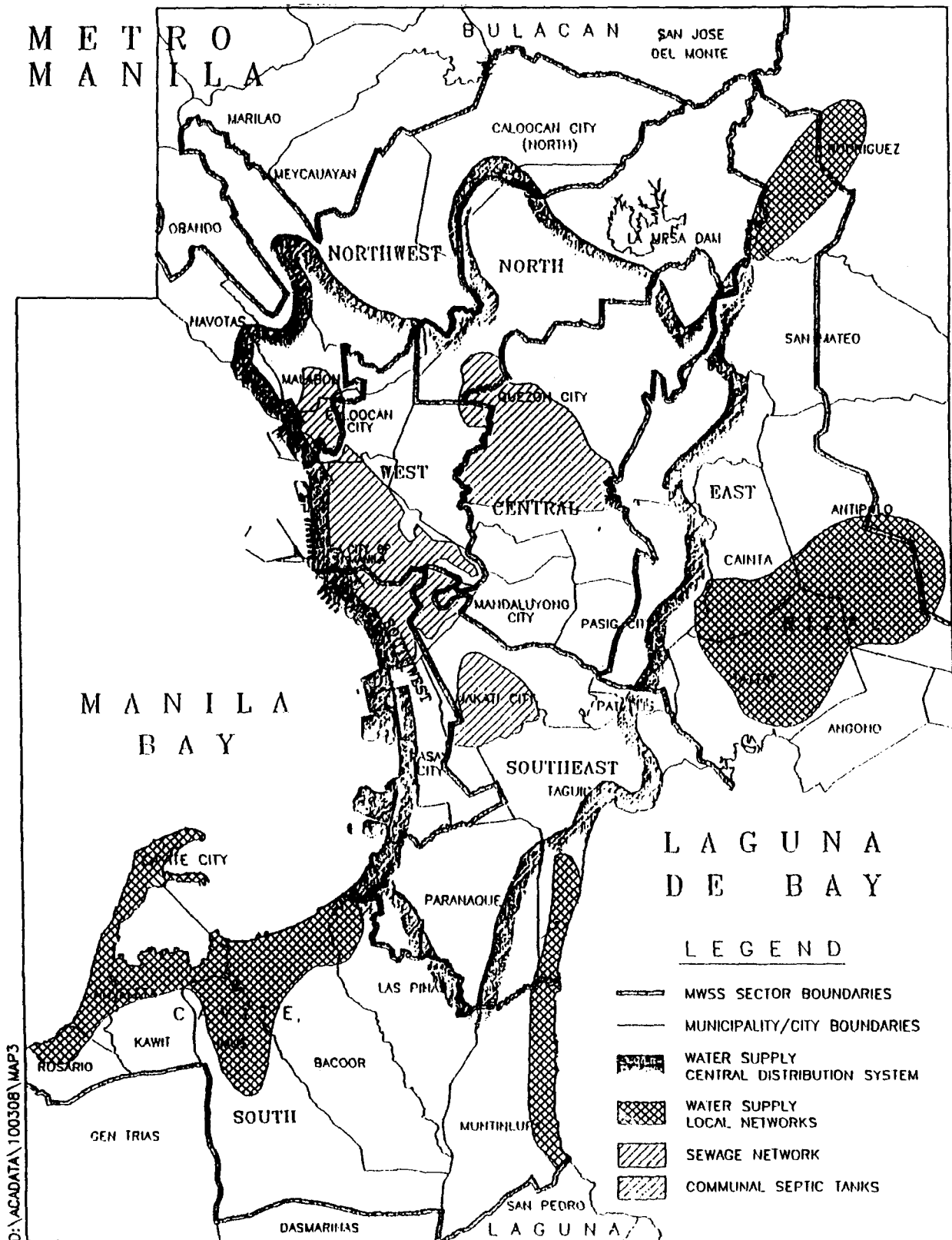
Source		Angat	Ipo Dam	La Mesa Dam	Groundwater
Capacity	storage (MCM)	850	6	45	N/A
	inflow (MCM/yr.)	1,700	128	36	45 (est.)
Operation	operated by	National Power Corp.	MWSS	MWSS	MWSS and private
	used for	- power - irrigation - water supply	water supply	water supply	- potable - industrial
Location	distance from Manila	58 km NE	42 km NE	20 km NE	all over the area
	position in the system	head resource collection	intermediate intake	storage	resource abstraction
Production	% of total	35%	40%	23%	

Source: MWSS

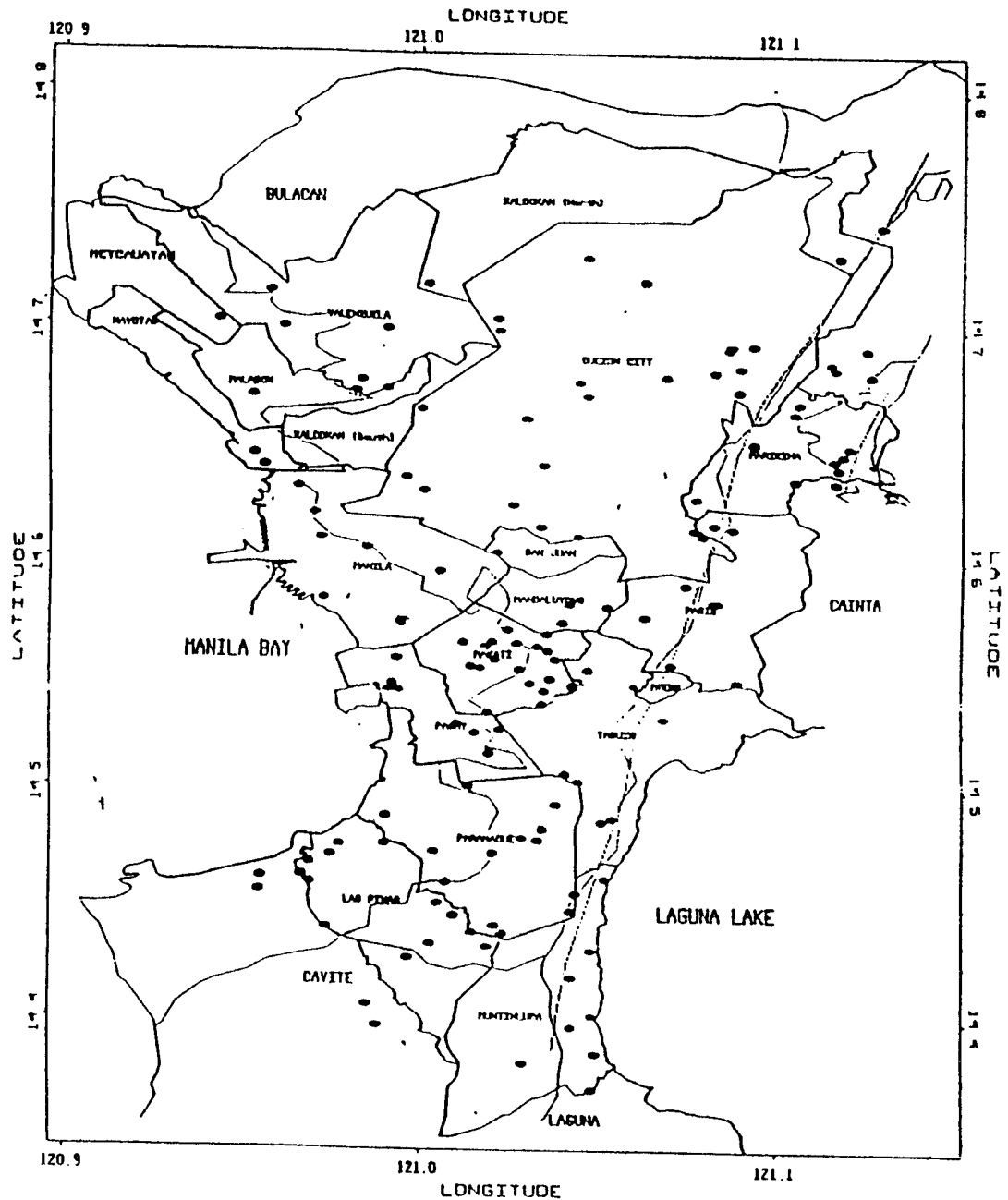
Currently, this agency supplies around 900 million cubic meters (MCM) of water annually to eight cities and twenty-nine municipalities in the NCR, Rizal and parts of Cavite (Figure 2). Of these, 875 MCM (about 97%) is from surface water from the basins of Angat, Ipo and La Mesa, and treated at the Balara and La Mesa treatment plants. Most of the treated water from the La Mesa Treatment Plant is sent to the Bagbag Reservoir while that from the Balara Treatment Plant flows to the San Juan Reservoir. The treated water is then distributed through the Central Distribution System (CDS). The remainder (3% of the current sources) is from groundwater drawn from MWSS deepwells, and injected directly into the distribution systems after chlorination. The MWSS groundwater source has a capacity of approximately 90,000 cubic meters per day (cu.m/d).

Historically, the water supply in Metro Manila as well as in most areas in the country has greatly depended on groundwater sources, and has been, therefore, the alternative source for areas unserved or inadequately served by MWSS. Thus, besides the MWSS deepwells, there are also more than 3,000 private wells which abstract approximately 310 million m<sup>3</sup> of groundwater per year (Figures 3 and 4). Shallow wells are also used to a certain extent. There are about 20,000 shallow wells whose pumpage is around 14

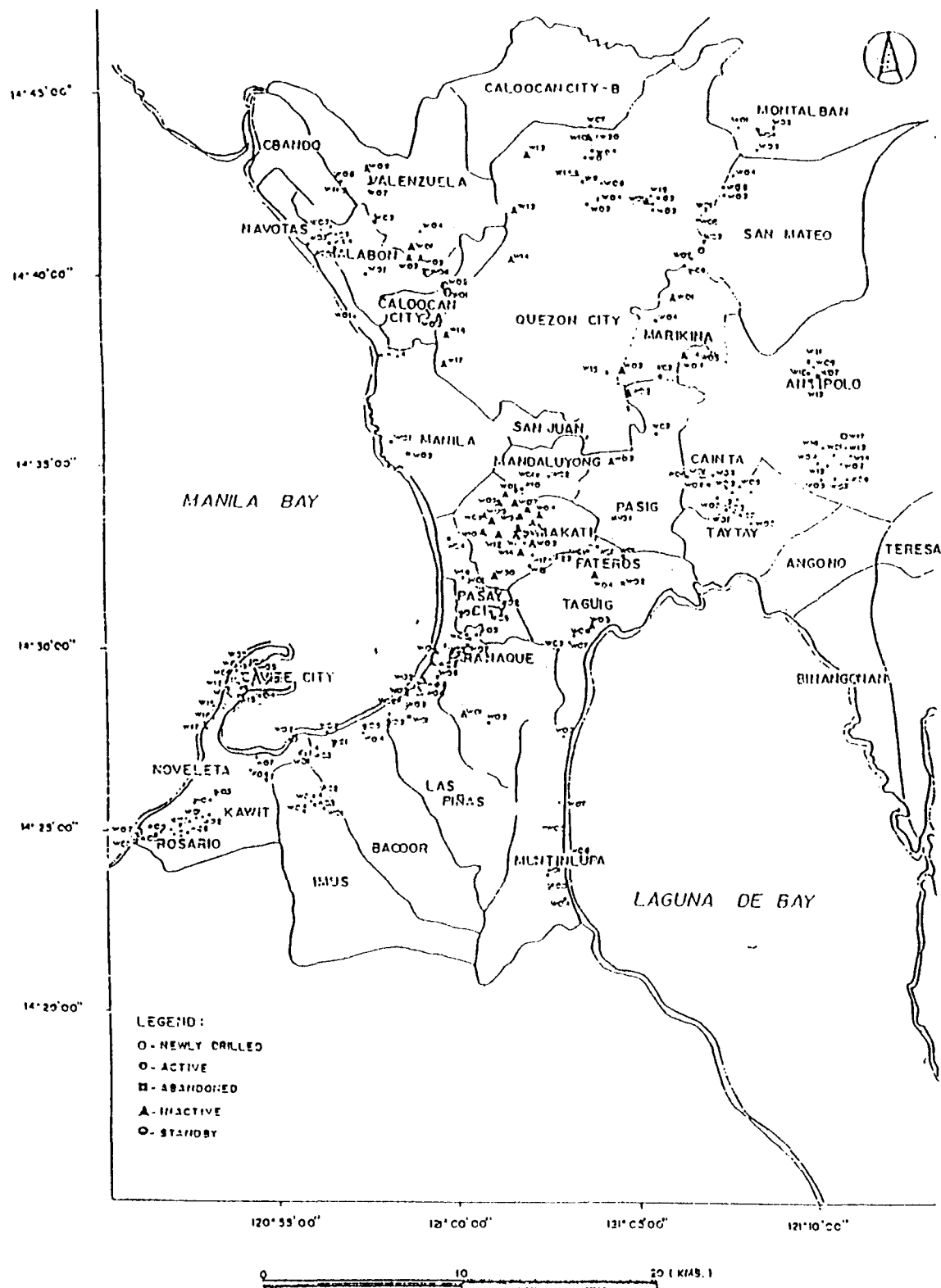
Figure 2. STUDY AREA



### Figure 3



**Figure 4. Private Wells with Permit from NWRB**





MCM in 1990. The shallow and deep wells were drilled for domestic supply, industrial and commercial use. Of the total withdrawal from groundwater, approximately 91% is drawn by private wells and 9% by the MWSS wells. Most of the groundwater is being extracted from the Guadalupe Formation.

### 2.1.2 Water Quality

Most of the surface water resources in Metro Manila are already contaminated. MWSS, therefore, has had to source water from river basins outside its service areas. Surface water diverted from the Angat, Ipo and Novaliches catchments are well protected, and meet the requirements of Class AA to A water. The raw water from the rivers and its catchments have good turbidity values, low mineral concentrations, sufficient natural alkalinity, and acceptable color values. The unabated pollution of Metro Manila's four major rivers (Pasig, San Juan, Tullajan-Tenejeros and Parañaque-Zapote) have made them fit only for limited navigation. Their biological oxygen demand (BOD) has become quite high while the dissolved oxygen (DO) levels are below standards for Class C<sup>1</sup> rivers. They are also contaminated with heavy metals and pesticides. Likewise, there are indications of increasing contamination of Laguna de Bay from human, agriculture and industrial development, and other non-point sources. The latter includes surface run-off containing fertilizers, pesticides and urban road sediments. For lake water to be fit for drinking, tertiary water treatment must eliminate toxic heavy metals and organic compounds.

Less visible, and generally of less public concern, is the water that lies underground. The uncontrolled development and excessive pumping of groundwater have caused a widespread decline of water levels in artesian aquifers. This has ensued in a considerable number of deepwells in the MWSS service area being affected by regional salinization, especially those in the coastal areas. Deep cones of depression also caused the upconing of connate or fossilised water in the inland aquifer, and seepage of brackish water along the Pasig River (IDRC-UP-NHRC, 1993). Of the 258 MWSS deepwells, 52 wells were abandoned, and 75 wells were inactive as of March 1991. As a consequence, new wells must be developed in the search for fresh water in deeper aquifers---and the cycle is repeated, subjecting more areas to salt water intrusion. Apart from salinization, groundwater may also be contaminated by point sources such as leachate from dumpsites, polluting industries, and underground storage tanks of gasoline stations and bus terminals (Pascual, 1992).

### 2.1.3 Sources of Recharge

The water resources of Metro Manila consist mainly of rainfall, surface runoff, and groundwater storage. It has two pronounced seasons: the rainy season from May to October, and the dry season from November to April. Average annual rainfall in this area, in which about 90% occurs during the rainy season, ranges from 1,900 mm to 2,200 mm. In spite of this seemingly large excess supply of water, the dependable streamflow comes only from the La Mesa or Novaliches watershed due to the highly

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<sup>1</sup> Class C - suitable for propagation and growth of fish and other aquatic resources.

polluted state of Metro Manila's surface waters. Moreover, the average net recharge to the aquifer was estimated to be 5% only of the average rainfall because of hydrogeological limitations such as aquifer impermeabilities and lack of effective natural recharge areas (JICA-MWSS, 1992).

## 2.1.4 Future Water Sources and Production Capacity

Several projects being targeted by MWSS to augment current water sources, are still in the feasibility stage, and funding for their implementation still have to be sourced. The following are on-going and planned projects designed to cope with increasing water demand:

- *Angat Water Supply Optimization Project (AWSOP)*. This project is expected to increase production of raw water from the Angat dam by 1,300 to 2,000 MLD (completed), augment the dispatch of treated water from La Mesa 2 by 900 MLD (approximately 50% completed), and increase distribution capacity (yet to start). The project cost is estimated to be US\$352 million.
- *Balara Water Treatment Plant Rehabilitation Project*. A US\$43 million-project to rehabilitate the Balara treatment plant (approximately 66% completed).
- *Umiray-Angat Transbasin Project*. This project was designed to augment the supply of raw water to Angat through the diversion of 900 MLD from the Umiray River. The project involves the construction of diversion dam, tunnel, distribution system and treatment plant, and is estimated to cost US\$166 million. The project also accounts for watershed erosion control and other mitigating measures to reduce environmental impacts.
- *Manila North-East Water Supply Project*. This project is proposed to supply water to the towns of Montalban and San Mateo in Rizal province, and Marikina, by rehabilitating Wawa Dam, intake structures, aqueduct and distribution system, and construction of water treatment plant and treated water reservoir for the polluted state Marikina River which feeds Wawa Dam. (A garbage dump is reportedly located within the protected area of the Marikina watershed.)
- *Rizal Water Supply Improvement Project*. This US\$45 million-project initiated to expand the service area within the Rizal province has been recently started. Water supply sources are Laguna de Bay and groundwater.
- *Manila South Water Distribution Project*. This project intends to expand service to Muntinlupa, Las Piñas, and Parañaque, and Bacoor, Cavite by diverting 300,000 cum/d from AWSOP. Project cost is estimated at US\$68 million.
- *Manila Water Supply Project – III*. The implementation of this project started in the early 1980s, but was deferred due to high costs (\$1 billion). The targeted supply source is Kaliwa River in Tanay, Rizal, and about 1,900 MLD will be supplied to around 5 million people. Project components are the construction of the Laiban Dam, tunnel, power plant, treatment plant, and treated water reservoir. MWSS is thinking of developing this project under the *build-operate-transfer* (BOT) scheme.

Table 2 presents the capacity of surface water sources being targeted by the MWSS. It was assumed that if the on-going and planned projects would proceed on schedule, then the surface water supply capacity would exceed the total water demand

but only in areas covered by CDS. The approach, therefore, is for groundwater to supply -- the fringe areas or areas not covered by the CDS. It was proposed that current sources be extended with surface water or that coverage of CDS be expanded, but this goes back to the original financial problem. Presently, the MWSS is undertaking rehabilitation projects to recover non-revenue water (NRW). The 1991 and 1992 expenditures on NRW reduction work amounted to P241.22 million and P227.74 million, respectively. The problem is that only about half of the amount to be recovered would be available for consumption due to leakages in the distribution lines and pilferage or illegal use.

**Table 2. Potential Capacity of Surface Water Sources**

Surface Water	Area of Watershed (sq. km.)	Capacity or Yield (MCM/day)
<i>Marikina River</i> 439 MCM/day was previously abstracted through Marikina Pumping Station and Wawa Dam * utilisation has been discontinued	282	1,280
<i>Laguna de Bay</i> * Construction of the Angono and Taytay waterworks using 38 MCM/yr. ** to be utilised as water supply for parts of Rizal and Cavite	922	2,592
<i>Umiray River</i> * water will be fed through the Angat system (recently started)	177	800
<i>Kaliwa River</i> * targeted for the Manila Water Supply Project III	276	1,909
<i>Kanan River</i>	290	3,170

Source: MWSS

## 2.2 Demand Conditions

Table 3 shows how much water is required in the service areas of MWSS vis-à-vis the estimated available water resources. The figures indicate a deficiency in water supply of around 559,000 cubic meters per day (cum/d) in 1995.

**Table 3. Water Availability**

	(cu. m. per day)
<i>Water Resources:</i>	560,000
Groundwater safe yield	100,000
Dependable streamflow (from La Mesa dam)	2,300,000
Surface water (from Angat-Ipo Dam)	2,960,000
Total	
<i>Water Demand (estimated)</i>	3,519,000
<b>Deficiency in water supply</b>	<b>559,000</b>
Rate of Overpumping of Groundwater	370,000

Source: Octaviano (1993).

## **2.2.1 Over-extraction of Groundwater**

Three sets of simultaneous observations of groundwater levels of 231 deepwells were carried out in November 1990, April-May 1991 and August 1991. From these measurements, groundwater maps were prepared. The results implied by the water balance computations and piezometric levels are the large drawdowns due to high withdrawal rates under conditions of low effective recharge (Roca, 1993). This means that groundwater is being mined from the Guadalupe Formation at rates that greatly exceed the low natural recharge rates. The combined total groundwater withdrawal of MWSS and the inventoried private deepwells in 1990 was estimated to be around 930,000 cu.m/d. Since the safe yield is only 560,000 cu.m/d, then the rate of over-extraction is 370,000 cu.m/d. This figure is much higher when the number of non-inventoried wells are taken into account. For the period 1982-1990, the estimated annual rate of mining the aquifer systems is 28.84 MCM, resulting in the lowering of the water table by 2.4 meters per year during this period (IDRC-UP- NHRC, 1994). It is estimated that the total groundwater withdrawal during 1990-96 has increased to about 1 million cum/d, and the groundwater level is continuously declining at an estimated rate of 6-12m per year (Haman, 1997). Increasing dependence on groundwater is due to the ability of MWSS to supply water to only 65% of the population and 20% of the industries; this capacity further aggravated by intermittent service.

The over-extraction has resulted in salt water intrusion and areas affected cover 4 cities and 11 municipalities, namely, Pasay City, Makati City (western part), Manila, Caloocan City (south), Las Piñas, Parañaque, Valenzuela, Malabon and Navotas in the NCR, and Bacoor (northern part), Imus (northern part), Kawit, Noveleta and Rosario in Cavite. Groundwater mining is ongoing in a 375 sq. km. area, about 47% of the main aquifer area (Haman, 1997).

## **2.2.2 Sectoral Uses of Water in Metro Manila**

The distribution of inventoried private deepwell pumpage is as follows: 49.2% for public and institutional users, 8.6% for commercial, and 42.2% for industrial use. In view of the type of water source used, about 40% of domestic water supply comes from groundwater and 60% from MWSS surface water while for the industries, only 18% have MWSS connections and as much as 82% have their own deepwells. Table 4 shows the volume of water, by type, of different water users in Metro Manila. Note that these figures are based on the billed consumption for MWSS supply (surface water) and the inventoried wells of MWSS and the private sector. Thus, they do not include the volume of illegal consumption and the number of non-inventoried wells. Among the industrial sectors, the major users of groundwater are in the manufacturing industries, namely, food and beverage, chemical and textile industries.

**Table 4. Distribution of Water Resources (in million cu. m/yr.)**

Water User	Type of Water Connection	Surface Water	Groundwater
Domestic	MWSS House Service Connection & Public Faucet Private Deepwells Private Shallow Wells	264.0	22.5 138.3 14.0
Commercial	MWSS Meter Connections Private Deepwells	117.5	8.1 39.0
Industrial	MWSS Meter Connections Private Deepwells	28.6	2.2 129.5
All Users	MWSS Meter Connections Private Deepwells	410.1	32.8 320.8

Source: JICA-MWSS (1992). *Study for Groundwater Development in Metro Manila*.

### 2.2.3 Non-revenue Water

The water consumption of illegal users and water losses during distribution were added to the estimate of total consumption of MWSS water supply. In 1990, surface water production of the MWSS was 875 MCM while groundwater pumpage was 33.3 MCM. In terms of usage, total surface water consumed through MWSS meter connections was only 410.1 MCM for the same year and 32.8 MCM for MWSS deepwells. The total volume sold represents only 42% of total production. Thus, 58% is "unaccounted-for water" or "non-revenue water" (NRW). The MWSS water bill for 1992 was ₱3,186.8 million, but the total water revenue or the amount actually collected was only ₱2,981.72 million. About 66% of the NRW is not really wasted in the sense that this percentage of NRW goes to illegal connections, and the remaining 34 percent of the NRW is due to leaks and meter errors. The percentage share of NRW to total MWSS production from 1984-95 is shown in Table 5.

## 2.3 Water Resources Management

### 2.3.1 Agencies Involved in the Development of Water Resources

The authority and responsibility for the development, control, protection and conservation of water resources in the country is vested in the State. This is accomplished through the various government offices which implement the water resources programs in the country. The National Water Resources Board (NWRB) was created to integrate all activities related to water resources. The other agencies responsible for the coordination and supervision of the Water Supply Subsector are the National Economic and Development Authority (NEDA), Department of Health (DOH) and Department of Public Works and Highways (DPWH). The quality of water is monitored through a tripartite body headed by the Environmental Management Bureau of the Department of Environment and Natural Resources (DENR), MWSS and DOH. About 32 agencies are involved in water-related activities in the country. All water resources development projects are required to be undertaken on a multi-purpose basis using a single river basin or an integrated basin approach (Sly, 1993).

**Table 5. MWSS Water Production and Sales (in million cu. m/yr)**

Year	Water Production			Volume Sold	Non-Revenue Water (%)
	Ground	Surface	Total		
1984	25.6	642.2	667.8	289.9	56.6
1985	29.5	757.4	786.9	302.9	61.5
1986	30.4	874.1	904.5	310.8	65.6
1987	27.9	834.8	862.7	336.5	61.0
1988	29.5	849.3	878.8	359.5	59.1
1989	29.0	859.1	888.1	375.8	57.7
1990	33.3	875.8	909.1	384.7	57.7
1991	33.9	779.6	813.5	386.5	52.5
1992	28.0	823.4	851.4	383.0	55.0
1993	25.7	907.1	932.8	397.3	57.4
1994	26.5	983.1	1,009.6	418.9	58.5
1995	27.2	948.7	975.9	426.5	56.3

Source: MWSS Corporate Planning Group, 1996.

### 2.3.2 Present System of Allocation and Water Supply Services

The Angat reservoir, which has an average flow of 60 cubic meters per second (cum/s), is used by three government agencies with allocations set in each of their water rights. First priority is given to power generation by the National Power Corporation. MWSS, which has second priority, withdraws 22 cum/s of available inflow for domestic, commercial and industrial uses. The National Irrigation Authority (NIA) withdraws 36 cu.m/s for its irrigation requirements. When NIA does not need to fully utilise its regular allocation, MWSS withdraws an extra 15 cu.m/s. Due to the recurring water crisis in Metro Manila (for instance, as a result of the El Niño phenomenon), MWSS has sought an extension of the increased allocation. This could, however, aggravate the situation if farmers would incur losses. If the water elevation in the dam dips down to 168m or below, NIA cannot withdraw its allocation since its diversion structures require water elevation higher than 168m. A study pertaining to the acquisition of the water allocation rights of NIA by MWSS was recently conducted.<sup>2</sup>

The water service is classified into three levels: (I) point source system, (II) communal faucet system, and (III) waterworks system. The MWSS was accountable to 750,000 households or concessionaires in 1990. Although 90% of the population in the study area is served, directly and indirectly, only 60% have access to piped water supply system or Level III services. As a consequence of inadequate coverage, there exist a water vending system and a number of deepwells without permits. In Metro Manila, water supply consists of individual house connections (599,754 in 1990), private wells, dug wells, peddlers, around 1,490 public/MWSS standpipes in blighted areas, and 66,574 commercial/industrial and other connections (FIES, 1990). MWSS estimated

<sup>2</sup> Young, R.A., personal communication, 1996.



that the illegal usage of its water served about 2.65 million people in 1990. Around 66% of NRW is accounted for by illegal connections.

### 2.3.3 Current Fee Structure

The NWRB is tasked to review and approve water rates to be charged by waterworks operators. Waterworks system operators are required to submit to NWRB an annual report of finances and operations. These reports form the basis for the determination of a tariff rate base in which the operators will be allowed a rate of return of not more than 12%. The average annual water fees, which range from ₱0.55 for a withdrawal rate of not more than 30 liters per second (lps) to ₱1.10 for a withdrawal rate of more than 50 lps, are charged for the following uses: domestic, irrigation, livestock, commercial, industrial, and power generation.

For the MWSS, the setting of water tariff is based on the attainment of revenue levels sufficient to sustain operations and maintenance as well as provisions for system expansion, changes in the foreign exchange rate, and debt servicing. It also applies a uniform tariff structure over its entire service area. The tariff structure follows a block schedule with different rates for four identified users: Residential-A, Residential-B, Commercial, and Industrial (Table 6). The overall average tariff, effective May 1992, is ₱6.43/cu.m. This tariff schedule has not changed in the past four years. It was recommended that MWSS seriously consider executing real increases in the price of water to properly reflect its scarcity value.<sup>3</sup> The increase in water tariffs must be accompanied, however, by improvements in water delivery services and in revenue collection policies.

There is also a minimal amount of environmental charge (10% of water bill) for those served by the MWSS deepwells. The sewer tariff is 50% of the water tariff for those connected to the Central Sewerage System. In some areas being serviced by MWSS with groundwater, rationing is being done (i.e., the water is supplied at certain hours of the day, and the water users are charged a flat rate). Some residential subdivisions have their own deepwells, and the consumers are charged a higher tariff rate than that of MWSS.

The other user of water from the Angat reservoir, NIA, charges irrigation fees from beneficiaries of national and communal irrigation systems. Since water for irrigation is distributed using open channels, and water flows from one farm to another, the area irrigated has become the basis for the irrigation water pricing policy rather than the volume of water used. On average, the rates are two cavans<sup>4</sup> of palay per hectare irrigated during the wet season, and three cavans of palay per hectare irrigated during the dry season, in the National Irrigation System (NIS). The cash value is computed at the prevailing support price of palay. Exemptions from payment are given to those who harvest less than 40 cavans per hectare. Farmer beneficiaries of the Communal Irrigation System (CIS) are charged amortization based on the cost of investment (direct

<sup>3</sup> As a result of the recent privatisation of the MWSS, the water tariff, as proposed by the new concessionaires, will go down to around ₱4/cu.m. in the West Zone and to ₱2/cu.m. in the East Zone. They are not allowed to increase their water rates in the next five years.

<sup>4</sup> A cavan is equivalent to 50 kg or 1 sack of palay.

cost only): 10% as equity during construction, and the balance is amortized in not more than 50 years at zero interest.

**Table 6. MWSS Water Tariff Schedule**  
(Effective May 1992)

<b>A. Industrial Use</b>		
First 25 cu.m. or connection	P	246.25 /connection
Next 975 cu.m.		9.85 /cu.m.
Over 1,000 cu.m.		11.55 /cu.m.
<b>B. Commercial Use</b>		
First 25 cu.m. or connection	P	226.25 /connection
Next 975 cu.m.		9.05 /cu.m.
Over 1,000 cu.m.		9.50 /cu.m.
<b>C. Residential</b>		
First 10 cu.m. or connection	P	28.00 /connection
Next 10 cu.m.		3.40 /cu.m.
Next 10 cu.m.		4.15 /cu.m.
Next 10 cu.m.		5.20 /cu.m.
Next 10 cu.m.		6.00 /cu.m.
Next 10 cu.m.		6.55 /cu.m.
Next 20 cu.m.		7.25 /cu.m.
Next 20 cu.m.		7.90 /cu.m.
Over 100 cu.m.		8.45 /cu.m.

Source: MWSS Corporate Planning Group

### 2.3.4 Management Issues

The key issues in the water resources sector are the following: insufficient coordination of more than 32 agencies; excess demand or water supply shortage due to increasing population and agricultural and industrial development; and pollution which aggravates water availability.

Water use regulation is achieved through administrative concession or "water permit" system. The present Water Code requires groundwater users to secure water permits from NWRB, except those users of shallow wells for domestic purposes. After securing the permits, however, users rarely measure and report groundwater levels, quality and pumping rate. Moreover, a number of industrial establishments have not applied for permits for their deepwells. Since shallow wells users are exempted from securing permits from NWRB, there is no inventory of the actual number of these users and their pumpage production. Thus, after investing in the water pumps, the groundwater users are, in fact, using the resource for free.

Groundwater mining is allowed as a temporary measure to solve the current availability limitations from surface water -- even if there is a critical threat from saltwater intrusion and possibly, land subsidence whose detrimental effects could be irreversible. The lack of systematic monitoring of groundwater levels and water quality can be

attributed to the insufficient resources of NWRB for such a task. MWSS has little incentive to institute and maintain a monitoring network for about 3% of its supply.

MWSS needs to reduce the number of illegal users, leakages, and non-revenue water (NRW). Before launching any leakage control program, there must be an assessment of the magnitude of total water losses, identification of the causes, and determination of leaks. Measures for the control of illegal use must be made and implemented. Significant reductions in NRW to acceptable levels could result in the avoidance of constructing new facilities. The costs of installing new meters and monitoring can be compared with the cost involved in constructing new facilities.

Another problem is families who have no access to MWSS water supply. They buy at higher prices from peddlers their water supply which may be of doubtful quality. Although the higher prices may reflect the scarcity of water, the families usually affected belong to low income groups. Furthermore, the water problem affects the small- and medium-scale industries.

In view of the pollution issue, the provision of sanitary sewerage systems should, likewise, be given as much importance as that of increasing water supply. The low priority given by the MWSS management to sewage collection and disposal has resulted in the increasing amount of untreated wastewater in the waterways and contamination of shallow wells. Likewise, proper disposal sites of solid wastes are needed since current garbage dumpsites are located near the reservoirs (La Mesa and Wawa Dams). The lack of water supply, in terms of quantity and quality, as well as water pollution have adverse effects on health. Waterborne diseases have killed 7,610 persons, mostly children, and caused about one million morbidity cases in 1991 (DOH, 1991). Periodic outbreaks of cholera, typhoid fever and dengue H-fever can be traced to the poor state of the water distribution systems and sewerage systems.

### 3.0 INDUSTRIAL DEMAND FOR WATER

Unlike ordinary goods that are consumed directly to derive satisfaction, the demand for water by industries is a derived demand. The goal of the firm is to minimise the total cost of production subject to the production function, and possibly, to other constraints imposed by environmental regulations (Bhatia, *et al.* 1992). This approach is based on various studies which look at demand management as a more viable alternative to purely supply augmentation projects, and explicitly consider the economic and environmental linkages. It is assumed that this industrial unit has information on various technological possibilities, and the alternative costs of conservation of water, recycling of treated water, and treatment of effluent. The demand for a certain input is usually postulated to be a function of the own price variable, price of substitutes, and output.

$$\text{Production Function: } Q = Q(L, K, M, W) \quad [1]$$

where  $Q$  denotes the total output;  $L$ ,  $K$  and  $M$  are the labor, capital, and other inputs (except water) used in production, respectively.  $W$  is the water used in the production process.

$$\text{Total Cost: } TC = p_L L + p_K K + p_M M + p_W W \quad [2]$$

where  $TC$  denotes the total cost of production, and  $p_i$  is the price of the  $i$ th input.

The objective of the firm is to minimise [2] subject to [1]. This results in the following first-order conditions:

$$p_L - \lambda \frac{\partial Q}{\partial L} = 0$$

$$p_K - \lambda \frac{\partial Q}{\partial K} = 0$$

$$p_M - \lambda \frac{\partial Q}{\partial M} = 0$$

$$p_W - \lambda \frac{\partial Q}{\partial W} = 0$$

$$Q = Q(L, K, M, W)$$

Solving for  $L$ ,  $K$ ,  $M$ , and  $W$  using the above equations will result in the following conditional demand functions:

$$L = L(p_L, p_K, p_M, p_W; Q)$$

$$K = K(p_L, p_K, p_M, p_W; Q)$$

$$M = M(p_L, p_K, p_M, p_W; Q)$$

$$W = W(p_L, p_K, p_M, p_W; Q)$$

Primary decisions on technology and outputs usually determine the amount of water required (gross water applied) per unit of output in the specific production process. Since there are other types of water sources from which the industries can choose, reliability or certainty of regular supply of a particular source, in addition to the intake costs, becomes quite important. Industry processes require water for any one or more of the following purposes: a) washing raw materials and equipment, conveying production inputs, and incorporation into the product; b) cooling and condensation, particularly in steam-electric generation plants; and c) in-plant sanitary and overhead purposes (e.g., grounds maintenance or food preparation in a company cafeteria).

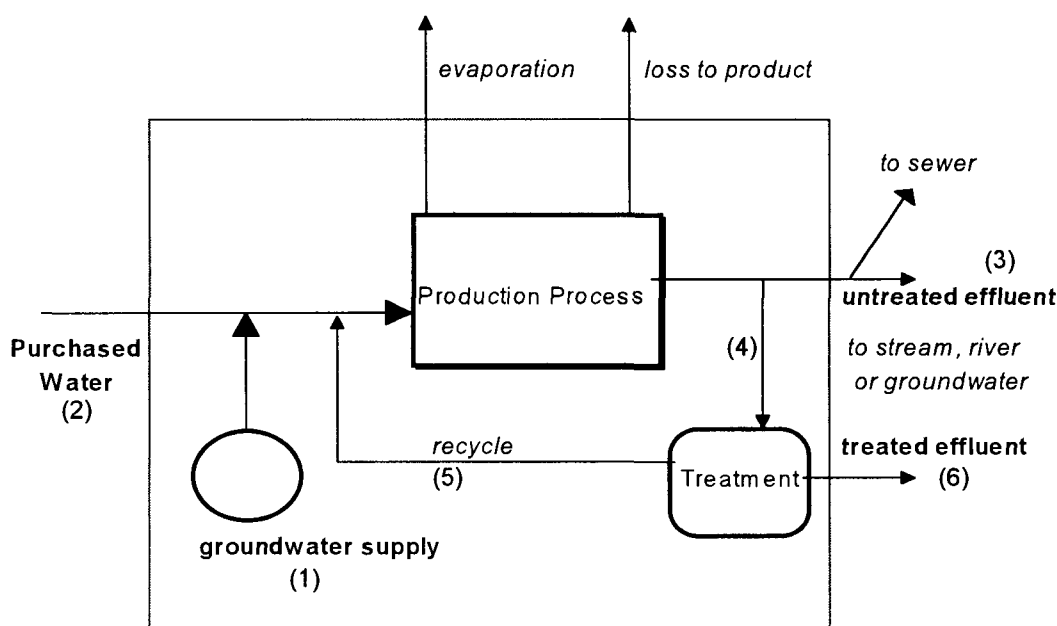
In addition to these, other factors that could affect the industries' demand for water. Some of these are: raw material quality, relative prices of inputs, desired output mix, reuse of water within or between production stages (recycling), and government regulations on product quality and on pollution discharges.

There are also quality requirements. For example, there are strict standards for in-plant personal use, boiler feed, and food and beverage industries, but few quality standards for cooling water.

Proper pricing of water is proposed to reflect the true value of this resource, and its acceptance as an economic good by consumers. Technological factors affect water demand requirements, and thus, constrain firms from reducing water consumption. The additional water charges, however, can act as incentives for firms to modify production processes, utilise conservation measures, such as recycling and treatment techniques, or use alternative water sources, whichever is possible. Incorporating a charge on effluents and wastewater in the water demand function would also serve as incentive for firms to treat wastes before discharging to a receiving water body or to recycle water and minimise total wastewater flows.

Figure 5 shows the water use of a single industry. This plant utilises its own water supply (from groundwater) and augments its water requirements by purchasing water from other sources. It has several other options regarding its water use and disposal: (a) it can directly discharge wastewater without treating; (b) it can treat water and recycle but discharge untreated effluents; and (c) it can both recycle and discharge treated wastewater and effluents.

**Figure 5: Single industry water use**



Source: Bhatia, Ramesh, *et al.* 1992.

### 3.1 Estimation of Industrial Demand for Water

The sources of various secondary data are the National Water Resources Board (NWRB), the agency tasked to integrate all water-related activities and from which permits for private deepwells are secured; the MWSS which undertook several studies on the water problem in Metro Manila; and the National Hydraulic Research Centre in the University of the Philippines which conducted the project on the development of a conjunctive-use water resources management model for the Laguna de Bay Basin, and assembled a valuable collection of water resources and other related data.

Primary data were gathered from selected industries. Private wells are concentrated in Parañaque, Las Piñas, Muntinlupa, Pasig City, Quezon City, Caloocan City and Valenzuela. In the industrial sector, groundwater is mainly used for the food and beverage, chemical, and textile manufacturing industries (JICA-MWSS, 1992). These sectors are also among the top users of waste disposal services provided by water bodies (delos Angeles, ENRAP-III 1995).

Information obtained from the survey conducted among different manufacturing establishments in Metro Manila was used to estimate the cost and demand functions. According to the theory of the firm, a firm will use inputs based on each marginal contribution to output or revenue relative to the marginal share to cost. Since the market price in the usual sense does not exist for self-supplied industrial water, either the marginal cost or the average cost (as the second best price) of intake water can be used as price proxy.

The demand for water by industries should also include the prices of other cooperating factor inputs used in the production process, and the impact of technological changes on the utilization of industrial water. However, such data from large firms are difficult to obtain. The cost of intake water consists of the construction or investment cost for the deepwell system, operating and maintenance costs, and treatment costs. Since most industrial water is self-supplied (utilising groundwater) or purchased at low cost, the costs of labor, capital, raw materials, and energy tend to dwarf the costs of water, even in industries that utilise enormous quantities of water. The average cost is used in this study as the price surrogate in the demand equation. Although economic theory suggests that marginal, not average, costs provide the basis for decision-making, previous studies on industrial water demand have used either the price of water purchased from a utility or some measure of average cost (De Rooy, 1974; Bower, 1966; Billings and Agthe, 1980; Ziegler and Bell, 1984). The following demand for intake water of self-supplied firms was estimated:

$$\log W = -3.693 - 0.798 * \log P_W + 0.79 * \log Y - 1.613 * S$$

$$(-1.356) \quad (-4.522) \quad (5.621) \quad (2.187)$$

$$R^2 = 0.8432 \quad \text{Adjusted } R^2 = 0.8413 \quad DW = 1.959 \quad F = 21.719$$



where  $W$ ,  $P_w$ , and  $Y$  are the volume of intake water, "price", and output, respectively.  $S$  is a dummy variable for the type of water source (groundwater or other water source). The coefficient for the price variable is significant and has the expected negative sign.

### 3.2 Projections of Future Demand

The demand for water by manufacturing industries is projected for 20 years. The volume of water demanded is basically influenced by the output to be produced or size of the industry, the type of industry, the type of water source and the cost or price of water. Future growth in the industry sector is assumed to be affected by the over-all performance of the national economy, the entry of new firms and the future plans of existing firms. An increase rate factor is computed using (1) the projected growth of the manufacturing industry sector in real terms as proxy for the entry of new firms and economic growth in the study area, (2) output elasticity to relate the consumption of water to the quantity of output that will be produced by the firms, and (3) price elasticity. The same method is used to project the water requirement of a typical establishment.

## 4.0 MARGINAL OPPORTUNITY COST OF WATER

### 4.1 Methodology

An efficient pricing policy is one that equates price of any good or service with the cost of producing an additional unit of it (i.e., to its marginal or incremental cost). Moreover, the cost of producing or consuming a resource should include the opportunities foregone due to that consumption. This section focuses on the estimation and implementation of MOC as applied to: (1) groundwater supply of industries located within the MWSS Service Area (Metro Manila and parts of Rizal), (2) MWSS supply, and (3) conjunctive use of groundwater and MWSS supply. The methodologies used for the estimation of the various elements of MOC, namely marginal production cost (MPC), marginal user cost (MUC), and marginal external or environmental cost (MEC), are described in this section, and the empirical results are provided. The user cost results from the depletion of the resource, thus, requiring alternative sources in the future. The external cost reflects the added cost of pumping imposed on other users, and the cost of untreated water disposal. The option which has the lower present value of costs is preferred.

#### 4.1.1 Marginal Production Cost

Capital indivisibility is a problem typical of water supply projects, where productive capacity is often installed to meet demand requirements for a number of years. Since costs will be marginal at certain times, and non-marginal at other times, this will result in significant fluctuations in price. Studies by Saunders, Warford and Mann (1977), indicate that when the problem of capital indivisibility exists, computing the marginal cost as the average unit cost of incremental output becomes more appropriate.

Based on the estimated future water requirements of the industrial sector and the existing water supply capacity of MWSS, a least-cost program that will meet the foregoing requirements has to be determined. The numerator in the following formula is

the present value of the least-cost investment stream plus the incremental operating and maintenance costs while the denominator is the present worth of the incremental volume of water produced over the period considered (Warford, 1994):

$$\text{Average Incremental Cost} = \frac{\sum_{t=1}^T (I_t + M_t - M_0) / (1+r)^t}{\sum_{t=1}^T (Q_t - Q_0) / (1+r)^t}$$

where  $I_t$  is the investment cost in year  $t$ ,  $(M_t - M_0)$  is the operations and maintenance cost in year  $t$  due to incremental consumption of water in year  $t$  or  $(Q_t - Q_0)$ ,  $r$  is the discount rate, and  $0$  is the base year.

#### 4.1.2 Measuring Pumpage Costs:

The basic equation relating pumpage to water table is:

$$A \cdot S \cdot \frac{\Delta H}{\Delta t} = R_n + \alpha W - W$$

where  $A$  is the area of the aquifer,  $S$  is the storativity coefficient,  $H$  is the water table,  $R_n$  is the natural recharge,  $\alpha$  is the return-flow coefficient, and  $W$  is the volume of water pumped from the aquifer (Gisser, 1983). During the period  $\Delta t$ , the water table had been lowered by  $\Delta H$ . The vertical distance between the water table,  $H$ , and the pumping elevation,  $P_E$ , termed the *lift* ( $P_E - H$ ), increases over time as the water level declines. Correspondingly, the pumping efficiency of wells declines as the lift increases. Thus, the falling water levels result in rising marginal cost of pumping. Let  $c$  denote the marginal cost of pumping per cubic meter per meter of lift (i.e., cost of energy to lift water), then the operating cost can be expressed as:

$$OC = c (PE - H)$$

#### 4.1.3 Marginal User Cost

The cost of future use foregone due to the depletion of a resource may be estimated as the cost of replacing the depleted asset at some future date (if substitutes are available). The marginal user cost (MUC) can, therefore, be estimated by getting the difference between the present value of the MPC of the substitute or replacement technology and the present value of the MPC of existing technology (Warford, 1994).

$$MUC = \frac{(P_b - C)}{(1 + r)^T}$$

where  $P_b$  is the price of replacement technology,  $C$  is the price of existing technology,  $r$  is the discount rate, and  $T$  is the time at which the replacement technology comes in or the switch to the backstop occurs.

#### 4.1.4 Marginal External Cost

External costs are uncompensated costs imposed on other parties, usually those who do not benefit from the exploitation activity. The type of externality that can be applied here is the technological externality which can be identified through physical means, such as through the hydrogeologic system (Young 1992). Furthermore, technological externalities can be categorised into reciprocal or unidirectional. In the case of reciprocal externalities, each agent imposes costs on all others, and each experiences costs imposed by others (Dasgupta 1982). An example of reciprocal externality is the jointly experienced increases in pumping cost as the water table declines when withdrawals exceed the recharge rate. Examples of unidirectional externalities are the contamination of the groundwater by leachate from dumpsites, leakage from underground storage tanks of gasoline stations, interface of aquifers with polluted surface water, or damages from subsidence of overlying lands.

This study focuses on the following external costs:

- (a) external cost associated with the private consumption or exploitation of the groundwater resource ( $MEC_1$ ):
  - (a.1) interference effect
  - (a.2) salt water intrusion
- (b) external cost associated with MWSS's water supply source (e.g., reservoir)
- (c) external cost associated with the production processes of the firm: pollution abatement cost for the untreated wastewater discharges ( $MEC_2$ )

#### 4.2 Estimation: MOC of Groundwater

Groundwater MOC has the following components: marginal direct or private cost (MPC), marginal user cost (MUC), marginal external cost associated with the over-exploitation of the resource ( $MEC_1$ ), and marginal external cost associated with effluent and wastewater discharges ( $MEC_2$ ).

The increase index used in projecting water demand by the industrial sector is also used in projecting the water requirements of a typical manufacturing establishment. Management has several options to meet this demand: pump groundwater, connect to MWSS system, buy water from tankers, or a combination of any of these sources. The marginal opportunity costs (MOC) corresponding to each option are estimated in this study. First, the MOC associated with the usage of water ( $MOC_1 = MPC + MUC + MEC_1$ ) is computed. This was done for a establishment located in areas with high rate of total pumpage, low groundwater stock and recharge rate, and/or within areas affected by saltwater intrusion (Area A), and likewise, for a establishment located in areas with moderate pumpage rates and outside the saltwater-intruded areas (Area B). There are various estimates of the marginal user cost (MUC) since a number of options exist

pertaining to the water source that a firm could choose from. The costs associated with consumption externality (e.g., saltwater intrusion, interference effect) are also estimated.

The marginal opportunity cost of water production by the MWSS is estimated using the AIC formula. Then,  $MEC_2$  or the marginal external cost resulting from the disposal of wastewater is estimated. Uncontrolled discharges of untreated wastewater can lead to the contamination of groundwater and surface water resources, which can also affect such diverse areas as human health, and fishery production. The marginal direct cost incurred by MWSS sewerage system operation in Metro Manila is estimated as an approximation of external cost.

#### **4.2.1 Marginal Private Cost**

For groundwater users, direct costs are investment or capital cost for the well system (about ₱2 million, at current prices), operating cost (based on the kilowatt-hour and electric bill) and maintenance costs (for annual cleaning of well, pump and motor, plus repair and replacement cost of major parts every five years). Average well yield depends on depth of the water table. A performance curve is used to determine well yield of a submersible pump.

Demand for water increases as production expands and the economy grows (given by the projected growth rate of the manufacturing industry sector and output elasticity of water demand). Operating time of the well increases as water demand increases while well yield decreases due to lowering of the water table. When operating time reaches nearly 24 hours, this signals the need to augment water supply to meet increasing demand. If Option 1 is chosen, the firm has to install an additional well. Well yield and its investment, operating and maintenance cost are added to those of the existing well.

Under a scenario that no pumping externality results from groundwater extraction (i.e., rate of extraction does not result in the lowering of the water table, interference and saltwater intrusion), the marginal private cost faced by an industrial user amounts to ₱52.67/cu.m.

#### **4.2.2 External Costs due to Over-extraction**

##### Increased MPC ( $MPC_2$ )

Where there are many users (also unregulated) and natural recharge is very low, the problems associated with common property resources (e.g., lowering of the water table), will result. MPC is computed using the average incremental cost or AIC formula for establishments located in Areas A and B, considering the different rates of decline of their respective water tables. This is an example of reciprocal externality wherein the cost of over-extraction, in terms of declining water tables and increasing pumpage cost, is absorbed by the pumpers themselves.

**MPC<sub>2</sub> (10% discount rate):**  
**Area A - P72.21/cu.m.    Area B - P66.97/cu.m.**

#### Interference Effect (MEC<sub>1a</sub>)

In addition, most of the deepwells were constructed near each other, resulting in the *interference effect* wherein pumping in one well affects yield of wells located within its 200-meter radius. Such effect can be measured in terms of changes in the drawdown, which is given by the difference between static water level and pumping water level.

This is a case of reciprocal externality where the damage is imposed on the users themselves. Ideally, wells should be constructed 200-600 m apart. In Metro Manila where groundwater is treated as a common property resource, this is not the case. Well data were gathered from establishments and residential units located within 1-km radius of sampled industrial establishments. The effect is a decrease in the efficiency of the pump or a drop in well yield by one cu.m. per hour for wells located less than 200 m apart. This translates into additional pumpage cost as shown below:

**AIC (10% discount rate):**  
**Area A - P 77.52/cu.m.    Area B - P 67.11/cu.m.**

#### Salt water intrusion (MEC<sub>1b</sub>)

There are additional costs if the firm decides to dig deeper for the freshwater aquifer instead of using the alternative sources. Moreover, the firm can also decide to treat or desalinise saline water if it cannot dig any deeper nor get access to alternative water supplies (another case of reciprocal externality wherein the cost has been internalised). Salt water intrusion due to excessive pumpage by industries also results in damage to other parties. Some shallow wells used for domestic purposes have become inactive because the wells yielded saline water (Table 7). In some cases, the wells have dried up, requiring rehabilitation or digging deeper for freshwater. The estimated marginal external cost in terms of the reduced life span and productivity of the wells and additional treatment expense is about P97.13/cu.m.

**Table 7. Number of Inactive and Abandoned Wells**

	Inactive (# of wells)	Abandoned (# of wells)	Total (# of wells)	Average Production (MCM/yr.)
Inventoried Wells				
INSIDE SWI AREA				
Private wells		392	392	49.91
MWSS wells	20	26	46	12.93
OUTSIDE SWI AREA				
Private wells		826	826	119.66
MWSS wells	55	26	81	19.20
<b>TOTAL</b>	<b>75</b>	<b>1,270</b>	<b>1,345</b>	<b>201.70</b>

SWI - salt water intrusion

Source: JICA-MWSS (1992).

Cost of relocation

A number of wells are either not operational anymore or had been abandoned due to any of the following: drying up, yielding dirty water, or caving in (Table 7). A joint JICA-MWSS study (1992) estimated that about 30% of the monitored wells were inactive or had been abandoned. The study also showed the foregone production from these wells, the number of relocated wells and the capital cost involved. In areas affected by salt water intrusion, some firms either dig deeper or new wells are constructed elsewhere. If those industries in Area A chose to relocate to other areas with good water supply, then they will face the same options, and therefore, the same MPC of water as those in Area B. There are, of course, costs involved in constructing new buildings or plants and transferring equipment to the new location. If one of the major reasons for relocating is the availability of water, then the value of water includes the cost of dislocation (e.g., new infrastructure), as well as the cost of obtaining water, as a bundle of attributes affecting a firm's decisions. The MOC of water in this case will, therefore, be very large.

**4.2.3 Cost of Alternative Water Sources**

Another MOC component is marginal user cost (MUC) which becomes relevant as water scarcity sets in, and groundwater resources are faced with the threat of eventual depletion. Regulation of pumpage is one method to control salt water intrusion and other externalities. In the following, the marginal user costs (together with the direct and external costs) were estimated for two types of scenarios. One is a depletion scenario, if one assumes that current extraction rates are not controlled. The second scenario assumes a conservation policy wherein the firm has to control its pumping rate and augment its water requirements by using alternative sources. In both scenarios, the cost of backup sources is estimated in addition to the cost of current groundwater supply source.



#### 4.2.3.1 Depletion scenario

A recent study showed that with the on-going rates of groundwater extraction, the aquifers (Guadalupe Formation) in Metro Manila will only be good for the next ten years until they run out of available drawdown (Haman, 1997). The backstop source is MWSS, assuming that the necessary infrastructure for surface water is in place. The marginal user cost, which is just the difference between the MPC without pumping externality and the MPC with pumping externality and backup source once depletion sets in, is estimated to be P25.28/cu.m. The total MOC<sup>5</sup> is about P176.83/cum.

#### 4.2.3.2 Conservation options

##### Conjunctive Use of Groundwater and MWSS Water (Option 2)

Under Option 2, the operating time of the well is regulated.<sup>6</sup> Since the well yield of the existing well is declining, to meet the establishment's water requirement, the firm decides to connect to MWSS. This is the backstop source of water. There is an initial investment cost involved in terms of connecting pipes, pump, and storage facilities. The operating cost associated with MWSS-supplied water is based on the water tariff charged by MWSS plus a 10%-environmental charge. This surcharge is added to the MWSS price to consider the external cost resulting from its production, for example reservoirs construction.<sup>7</sup> This price, however, still does not reflect the true economic cost of MWSS water supply, as can be gleaned from the difference between the MOC of MWSS water and its water tariff.<sup>8</sup> The investment, operating and maintenance costs for the original deepwell are added to that of the MWSS-supplied water. AIC is then computed. This second option resulted in lower opportunity costs compared to the first option of getting the entire water supply from groundwater. The pumpage rate is also assumed to be regulated in Area B to control further intrusion of salt water and to lessen the depletion rate. The difference between the AIC of installing additional wells (MPC<sub>2</sub>) and the AIC of the second option amounts to P19.71/cu.m. in Area A and P16.88/cu.m in Area B.

There is a small difference between the AIC (or MPC) in the case where there are no pumping externalities (areas with aquifers having large storage capacity and high rates of natural recharge, for example) and the AIC of Option 2 in both areas.

<sup>5</sup>  $MOC = MPC_2 + MEC_{1a} + MEC_{1b} + MUC + MEC_{1c}$ , where a 10%-environmental surcharge is used for  $MEC_{1c}$ , to reflect the external cost associated with the backup source, i.e., MWSS-supplied water.

<sup>6</sup> In Art. 32 of the Philippine Water Code, the NWRB can promulgate rules and regulations, and declare the existence of a "Control Area" for the coordinated development, protection and utilisation of groundwater and surface water. The regulated areas for groundwater pumpage will cover the coastal area of Metro Manila or 4 cities and 11 municipalities, after considering the present piezometric heads, positions of saline water intrusion, future plans for surface water supply, etc. (JICA-MWSS, 1992).

<sup>7</sup> This environmental charge are levied only in areas where groundwater is used by the MWSS for its supply.

<sup>8</sup> The MOC of MWSS is estimated to be P82.67/cu.m., using 10% discount rate, while the current average tariff charged to industrial users is P11/cu.m. The MWSS tariff considers only the operating costs, and an additional Currency Exchange Rate Adjustment (CERA) charge to cover the cost of servicing MWSS's foreign debt. The higher MOC reflects or includes the investment or capital costs, and can be considered as the subsidy extended by the national government to MWSS.

Regulation of pumpage in both areas, however, will yield benefits since carrying out of Option 2 results in lower opportunity costs as compared to Option 1.

MPC (10% discount rate):	Without pumping externality:	P52.67/cu.m.
MPC <sub>2</sub>	Option 1: Area A - P72.21/cu.m. Area B - P66.97/cu.m.	
MPC <sub>2</sub> + MEC <sub>1a</sub>	Option 1: Area A - P77.52/cu.m. Area B - P67.11/cu.m.	
MPC <sub>2</sub> + MEC <sub>1a</sub> + MEC <sub>1b</sub>	Option 1: Area A - P174.65/cu.m.	
MPC <sub>2</sub> + MEC + MUC:		
	Depletion scenario: P176.83/cu.m.	
	Conservation scenario (no MEC <sub>1a</sub> and MEC <sub>1b</sub> ):	Option 2: Area A - P52.50 Area B - P50.09

#### Cost of MWSS-supplied water (Option 3)

Under Option 3, all industries and huge water users are required to refrain from pumping the aquifers to allow some period for replenishment. The firm has to get its entire water supply requirements from MWSS, the backstop source. The water price charged by MWSS is the only operating cost involved. Initial capital or investment costs are incurred with the installation of storage tanks, meters, connecting pipes, etc. The AIC is only P17.07/cu.m., or P18.41/cu.m. if including a 10%-environmental charge, using 10% discount rate.

If MWSS reflects the true value of its water supply in its tariff schedule, then the MOC is higher, at P82.67/cu.m., (still lower than the MOC of Option 1 for Area A, at P176.83/cu.m.). The setting of water tariff is more of a political decision, however, rather than an economic one (before the MWSS privatisation).

#### Cost of water from tankers (Option 4)

Another option for those industries located in Area A is to buy their water supply from tankers once pumpage regulation is required. AIC, with water from tankers as the alternative supply, is P123.28/cu.m., applying a 10% discount rate. Current price charged by tankers is P70/cu.m.

### **4.2.4 Cost of Wastewater Discharges**

#### Abatement cost

The marginal external cost in terms of the wastewater discharges from industrial establishments is also computed. The pollution abatement cost literature proposes a nonlinear cost function, usually of the Cobb-Douglas form. In the present case, the following function is estimated:

$$C = e^a P^b D^c$$

where  $C$  is the total cost of abatement,  $D$  and  $P$  are quantities of wastewater and pollution concentration, respectively. The marginal cost of a unit change in water quality,  $P$ , given  $D$  is

$$\frac{\partial C}{\partial P} = e^a b P^{b-1} D^c$$

The costs of primary and secondary treatment for *BOD* (biological oxygen demand) for the food, beverage, chemical and textile industries are used to estimate the abatement cost function. The parameter *BOD* measures the sufficiency of dissolved oxygen in the water body for the aerobic decomposition of organic wastes. The higher the *BOD* load of the wastewater, the more polluted the water body becomes. The cost entailed for the wastewater treatment facility is regressed against *BOD* concentration and volume of discharges (plant capacity).

$$\begin{aligned} LCOST &= -1.135 + 0.542*LBOD + 0.376*LDISC \\ &\quad (-4.753) \quad (2.387) \quad (10.134) \\ R^2 &= 0.879 \quad \text{Adjusted } R^2 = 0.863 \quad F = 54.59 \end{aligned}$$

where  $LCOST$  is log of abatement cost,  $LBOD$  is log of *BOD* concentration, and  $LDISC$  is log of volume of treated wastewater discharges. The marginal abatement cost is as follows:

$$MC = 0.542 * \{e^{-1.135} LBOD^{0.542-1} LDISC^{0.376}\}$$

A pollution charge equal to the marginal cost of abatement should be imposed to control industries' organic and wastewater discharges. Due to constraints on resources and monitoring equipment, only *BOD* and suspended solids (*SS*) are regularly monitored and used to assess water quality conditions. These parameters are indicators of the impacts of industrial and domestic sewage discharges, but other adverse impacts are not adequately indicated. The problem of *BOD* in the lake can be attributed more to domestic wastes (72%) rather than to industry (14%), so the effect of controlling *BOD* from industries on lake water quality will be minimal if there is no corresponding control on the disposal of domestic wastes. Pollution control in the industrial sector should be directed more towards its disposal of toxic metals and hazardous wastes.

### Cost of damages

The four major rivers in Metro Manila are highly polluted and fit only for limited navigation. Laguna de Bay, a lake that drains Metro Manila and neighboring provinces, has an important contribution in terms of fishery production and its potential as a source of water supply for the metropolis and adjacent areas. A number of fish kill incidents in the lake as well as in Manila Bay were attributed to toxic waste dumping by industries. The results from the MEIP Valuation Study for Laguna de Bay (1994) showed that the cost of abatement was exceeded by the value of potential damage avoided if there is pollution control.

The pollution in the lake affects directly the cost of water treatment and fishery production, and indirectly the duck-raising industry. Without additional pollution control, the potential economic loss due to declining fishery production amounts from P7.47 billion to P10.98 billion (MEIP 1994). Open or capture fishery and mollusks have registered reductions in their net present value (NPV), but pen cultures seem to be less affected by the deterioration of water quality.

The water from the lake is currently used for domestic purposes in the towns of Angono and Taytay in the Rizal province. The proposed Cavite Water Supply Project (CWSP) will also tap the lake water. To make the lake water potable, tertiary and chemical treatment methods are required to eliminate toxic heavy metals and organic compounds. In proportion to the additional pollution loadings to the lake, the average increase in treatment costs will amount to P2.4 to 4.4 million annually for the period 1994-2000 (MEIP 1994). These additional costs can be avoided if pollution control facilities are in place.

In terms of waterborne diseases, no direct linkage to the rivers and the lake has been established. The health effects could be attributed, however, to the lack of water supply and sanitation and sewerage facilities, and to the fact that organic wastes (source of BOD and growth of micro-organisms and insect vectors) comprise the bulk of wastes directly discharged to most water bodies in Metro Manila. Only about 15% of the population is served by the communal septic tanks and sewerage system. The Ayala Sewerage System, which serves the "exclusive" villages in Makati City, has a wastewater treatment facility, while the Central Sewerage System being operated by the MWSS is actually just a sewerage collection system that leads to an ocean outfall in Manila Bay.

Due to lack of direct dose-response coefficients for waterborne diseases, attribution factors<sup>9</sup> were used to account for the morbidity cases that result from water pollution. In the NCR, among the leading morbidity cases are diarrheal diseases (which include typhoid and cholera), viral hepatitis and dengue H-fever (DOH 1991). The cost of excess mortality was estimated using two approaches: (1) human capital approach, and (2) willingness to pay (WTP) approach. The total damage to health (cost of morbidity and excess mortality) in the NCR ranges from P79.954 million, using the human capital approach, to P1,666.67 million based on willingness to pay to avoid the damage from pollution (Ebarvia and Padilla 1996). WTP would roughly be around P208.33 per person.

#### **4.3 Estimation: MOC for MWSS**

##### **4.3.1 Marginal Opportunity Cost of Water Production**

About 97% of MWSS's water production comes from surface water (Angat and La Mesa reservoirs), and 3% from groundwater. As much as 56% of water produced in 1995 is unaccounted or non-revenue water. Because of the high percentage of non-revenue water, the marginal direct cost (MDC) in terms of (1) the volume of water

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<sup>9</sup> These attribution factors were provided by experts from the U.P. College of Public Health (ENRAP-III).

produced, (2) the volume of water produced less the volume of water lost due to leakage and broken pipes, and (3) the actual volume of water sold (equal to volume of water produced less the volume of non-revenue water) are estimated.

The water supply expansion and demand requirement projected by MWSS are based on current consumption and growth in the areas currently covered by the Central Distribution System, and on meeting the reduction target for NRW. The current consumers of MWSS, however, constitute only about 65% of the population (domestic users) and 20% of the industries. Thus, the same proportion of unserved sectors (which are not included in the MWSS estimated projections of demand) will still have to rely on groundwater for their water needs. The reliance on groundwater could have been less if the NRW reduction program was successful (i.e. losses were translated into supply for the unserved sectors). Furthermore, the reduction in non-revenue water will ease the pressure on MWSS to look for other sources. For the period 2000-2015, MWSS targeted a reduction of NRW to 25%.

NRW is attributed to illegal users, leaks, and meter errors. About 65.3% of the water produced goes to illegal connections, and 35% of the water produced is lost due to leakage in the distribution system. The NRW percentage attributed to illegal connections shows how much of the water is used (and therefore not wasted), but not paid for. Thus, only the value of the actual volume of water that is not actually (economically) wasted would be the opportunity cost of MWSS water. Due to these leakages, the MOC increases from P68 per cu.m. to P82.67 per cu.m.

The value of the water actually sold (only 42% of water produced) by MWSS is quite high. Comparison of the MOC corresponding to the volume produced and volume actually sold indicates the implicit costs incurred by MWSS due to NRW, and the losses in terms of social welfare. The difference constitutes the cost being passed on to the legal consumers and to society – already suffering from inadequate water supply. Those sectors not legally connected to MWSS and using the resource for free, are therefore, receiving amenities not available to the rest of society.

MC of volume produced	P68.04/cu.m.
<b>MOC of volume produced less leakages</b>	<b>P82.67/cu.m.</b>
MC of volume sold	P140.00/cu.m.

### External costs

Of the on-going and proposed projects of MWSS, the Umiray-Angat Transbasin Project (UATP) and the Manila Water Supply Project-III would involve the construction of dams. The latter project has been deferred due to the very high cost involved (around P1 billion, excluding social and external costs). The external costs associated with the UATP involve resettlement issues (4,600 people in the Umiray basin and unprecised number of nomadic Dumagat tribes), impacts on wildlife, fish, biomass removal and erosion (due to clearing of 45 ha within the Angat watershed), and changes in water quality downstream of the diversion weir.

The families affected depend mainly on logging and gold panning for a living, and average family income is only ₱2000/month. They can be resettled in areas near the watershed and then compensated, or hired as part of the watershed management project. This will give them alternative occupations, and control their logging activities in the watershed.

According to the environmental impact assessment conducted for the feasibility of this project, wildlife in the vicinity of the work sites may be temporarily affected during construction, but no endangered species will be threatened. The abstraction of river flow will reduce the discharges, and lower water levels in the Umiray River's downstream reaches. The impact on river fishery will be locally significant (about 3 km downstream of the diversion weir), but of minor importance over the entire impact area of the project. Navigation will also be affected, especially during the dry season, and consequently, the normal haulage of goods and supplies, and transportation of people. Financial subsidies were proposed (by the proponents) for the creation of store houses.

Since mitigation of these impacts are project components, the external cost associated with this problem is already incorporated in the reported capital and O&M costs. An agreement was reached wherein the new concessionaires of MWSS will assume financing, including loans of this project. To maintain the water level and quality in the Angat-Ipo dams and control the impacts of soil erosion and siltation, watershed management needs to be undertaken, but this is a separate project.

#### **4.3.2 Marginal Direct Cost of Sewerage System**

The external costs associated with the disposal of (untreated) wastewater can be estimated either from the cost of damages or from the cost of abatement needed to prevent the occurrence of the damages. Upgrading the facilities and extending the coverage of the sewerage system for the collection and treatment of sewage and wastewater by the MWSS is a form of abatement measure. These are considered one of the concessionaire's responsibilities under the MWSS privatisation plan.

The marginal direct cost incurred by MWSS in its operation of sewerage system is estimated only for the period 1984-1995. Only the cost of desludging the communal septic tanks which form part of the sewerage system has been projected by MWSS. MDC is about ₱73.56/metric ton. Households connected to the Sewerage System and the communal septic tank system are charged sewerage fees equal to 50% of the water bill.

#### **4.4 Effects of MOC-Pricing**

The least-cost option is the conjunctive use of groundwater and MWSS-supplied water (surface water). This would require the regulation of pumpage, especially in areas affected by salt water intrusion, and where there is a significant decline in the water table. In recent years, the water level in these areas has declined at a rate of 6-12 m annually. At this rate, the main aquifer can tolerate overpumping for another 10 years

before pumping wells will run out of available drawdown (Haman, 1997). Table 8 shows the different marginal opportunity costs of the various options for the industrial use of water. Discount rates of 5%, 10% and 15% were also considered. The estimated MOCs also showed sensitivity to the level of discount rate used.

#### 4.4.1 Price Responsiveness of the Industrial Demand for Water

It has been suggested that an increase in the price of water is a preferable alternative to rationing if there is a shortage. The effectiveness of such a policy depends upon the sensitivity of users to changes in prices. Several studies have been conducted on the demand for residential water, and have concluded that price does not appear to have a significant impact, at least over a certain range of prices. There are only a few studies done on the industrial demand even though about half of all water withdrawals is accounted for by manufacturing activities. One reason for this is that most of the large and heavy water-using firms utilise water from a self-supplied source or pump directly from the ground or from a nearby river or lake. These studies have shown, however, that the price elasticity of demand for water was found to be higher for the industrial users than for the domestic users.

In this study, the estimated equation for the demand for water by industries provides some evidence that firms do respond to increases in water price even though the size of price elasticity is slightly less than unity. Price elasticity of -0.8 shows that a percentage increase in the price of water will reduce quantity demanded by 80 percent, *ceteris paribus*. The output elasticity, however, is positive, and may counteract the price effect. Thus, the most suitable policy would include not only a pricing policy, but a mix of regulatory, institutional and structural measures.

#### 4.4.2 Effects on the Final Output of the Economic Sectors

As an input to production, increasing the price or charging for the use of groundwater will have an impact on the production costs of the firm. The input-output table (I-O) is utilised to see the possible outcome of MOC-pricing on the output of the different economic sectors. Table 9 shows the results of the I-O simulations.

Water costs are usually a small fraction of total costs, but increasing the price of water resulted in changes in the final price of the manufacturing sector's output. Using the MOC for groundwater users in Area A (Scenario 2-b) as the price of water, higher price impacts can be noted on the following manufacturing sectors: beverage, other food, chemical products, transportation equipment, and on the services sector. Increasing the price of water, by using the estimated least marginal opportunity cost of water (Scenario 5 and 6) as the basis for the new water price, resulted in higher impacts on the final price of the beverage and services sectors only. Thus, the implementation of a pricing policy, which properly reflects the opportunity cost of an important resource, will have repercussions mainly on the beverage industry and services sector.

**Table 8**  
**Simulation Results : Marginal Opportunity Costs of Water**  
**for a Manufacturing Establishment in Metro Manila**  
(in pesos per cubic meter)

SCENARIO	DISCOUNT RATES		
	5%	10%	15%
1. all areas water source: groundwater * no pumping externality	42.13	52.67	63.88
2. Area A water source: groundwater			
2-a Option 1 : install additional wells ( $MPC_2$ )	66.98	72.21	80.34
2-b -- with interference ( $MEC_{1a}$ ) & salt water intrusion ( $MEC_{1b}$ )	169.61	174.65	180.54
3. Area B water source: groundwater			
3-a Option 1 : install additional wells ( $MPC_2$ )	63.60	66.97	73.15
3-b -- with interference effect ( $MEC_{1a}$ )	63.74	67.11	73.27
4. water source: groundwater back-up source: MWSS (Option 2 with depletion scenario) MOC ( $MPC_2 + MEC_{1a} + MEC_{1b} + MUC + MEC_{1c}$ )	163.67	176.83	189.80
5. Area A original water source: groundwater Option 2 : connect to MWSS ( $MPC_2 + MUC + MEC_{1c}$ )	43.89	52.50	62.55
6. Area B original water source: groundwater Option 2 : connect to MWSS ( $MPC_2 + MUC + MEC_{1c}$ )	41.66	50.09	60.03
7. All areas Option 3 : fully supplied by MWSS			
7-a -- using MWSS's water tariff	16.06	17.07	18.34
7-b -- using MWSS's water tariff plus environmental charge	17.42	18.41	19.67
7-c -- MWSS's MOC	85.58	82.67	79.37
8. Area A original water source: groundwater Option 4 : buy water from tankers	120.93	123.28	126.81



**Table 9**  
**Effect of Implementing MOC-Pricing on Different Economic Sectors**

SECTOR	Scenario								
	1	2-a	2-b	3-a	3-b	5	6	7-c	8
1 Agri., fishery & forestry	0.25	0.39	1.07	0.35	0.35	0.25	0.36	0.46	0.73
2 Mining	0.16	0.24	0.68	0.22	0.22	0.16	0.23	0.29	0.46
3 Meat & meat products	0.21	0.33	0.90	0.29	0.30	0.21	0.30	0.39	0.61
4 Milk & dairy	0.20	0.32	0.88	0.29	0.29	0.20	0.29	0.38	0.60
5 Canning	0.19	0.30	0.82	0.27	0.27	0.19	0.27	0.35	0.56
6 Coconut & vegetable oil	0.21	0.33	0.92	0.30	0.30	0.21	0.31	0.39	0.63
7 Food processing	0.18	0.28	0.77	0.25	0.25	0.18	0.26	0.33	0.53
8 Other food	0.40	0.62	1.71	0.56	0.56	0.40	0.57	0.73	1.16
9 Beverage	0.72	1.12	3.10	1.01	1.02	0.72	1.04	1.33	2.11
10 Tobacco & cigarette	0.21	0.32	0.88	0.29	0.29	0.20	0.30	0.38	0.60
11 Textiles	0.17	0.26	0.72	0.23	0.24	0.17	0.24	0.31	0.49
12 Clothing	0.13	0.20	0.55	0.18	0.18	0.13	0.18	0.23	0.37
13 Leather	0.19	0.29	0.80	0.26	0.26	0.19	0.27	0.35	0.55
14 Wood & wood products	0.22	0.34	0.94	0.31	0.31	0.22	0.32	0.40	0.64
15 Paper & paper products	0.19	0.30	0.83	0.27	0.27	0.19	0.28	0.36	0.57
16 Printing & publishing	0.18	0.28	0.79	0.26	0.26	0.18	0.26	0.34	0.54
17 Basic chemicals	0.19	0.29	0.79	0.26	0.26	0.18	0.27	0.34	0.54
18 Fertilizers	0.17	0.27	0.74	0.24	0.24	0.17	0.25	0.32	0.50
19 Synthetic resins	0.16	0.25	0.69	0.23	0.23	0.16	0.23	0.30	0.47
20 Pesticides & insecticides	0.19	0.29	0.80	0.26	0.26	0.19	0.27	0.34	0.55
21 Paints	0.18	0.29	0.79	0.26	0.26	0.18	0.27	0.34	0.54
22 Drugs & medicines	0.17	0.26	0.73	0.24	0.24	0.17	0.24	0.31	0.50
23 Soap & detergents	0.18	0.28	0.76	0.25	0.25	0.18	0.26	0.33	0.52
24 Misc. chemical products	0.23	0.36	1.00	0.33	0.33	0.23	0.34	0.43	0.68
25 Petroleum products	0.11	0.17	0.47	0.15	0.15	0.11	0.16	0.20	0.32
26 Rubber	0.15	0.24	0.66	0.21	0.22	0.15	0.22	0.28	0.45
27 Plastic	0.17	0.26	0.71	0.23	0.23	0.16	0.24	0.31	0.48
28 Non-metallic	0.17	0.27	0.74	0.24	0.24	0.17	0.25	0.32	0.50
29 Metallic	0.18	0.29	0.79	0.26	0.26	0.18	0.26	0.34	0.54
30 Non-elect mach	0.15	0.24	0.65	0.21	0.21	0.15	0.22	0.28	0.45
31 Elect prod	0.20	0.31	0.86	0.28	0.28	0.20	0.29	0.37	0.58
32 Transpo eqpt	0.25	0.39	1.08	0.35	0.35	0.25	0.36	0.46	0.73
33 Misc. manufactures	0.10	0.15	0.41	0.13	0.13	0.10	0.14	0.18	0.28
34 Construction	0.23	0.36	0.98	0.32	0.32	0.23	0.33	0.42	0.67
35 Electricity & gas	0.11	0.17	0.46	0.15	0.15	0.11	0.15	0.20	0.31
37 Services	0.79	1.22	3.37	1.10	1.10	0.78	1.13	1.45	2.29

#3-33: manufacturing sectors

## 5.0 SUMMARY OF RESULTS AND RECOMMENDATIONS

The focus of this paper is the estimation of the marginal opportunity cost (MOC) involved in meeting the water demand requirements of the industrial sector, and determining the right mix of pricing, fiscal and regulatory instruments for the efficient use of groundwater resources. The main water source of industries in Metro Manila is groundwater (80%). Only about 20% gets MWSS-supplied water, and some must augment their water requirements by buying water. Simulation tests were done at the plant or establishment level, and different scenarios were developed in order to evaluate the least-cost program. Table 8 presents the resulting MOCs for the different options considered in this study.

The most expensive option is to relocate (Option 5)---not feasible for some industries. The results show that to continue using groundwater as the only source of water supply in Area A (Option 1) consequently leads to high marginal opportunity costs due to external and depletion (user) costs. The lower-cost option between the fully

groundwater-supplied option (Option 1) and fully MWSS-supplied option (Option 3) is the latter option, using either the MWSS water tariff or applying water production MOC (net of leakages) of MWSS. The least-cost option is to have a conservation policy, such as the conjunctive use of groundwater and MWSS-supplied water (Option 2). This would require controlling groundwater pumpage, and then connecting to MWSS. The MOC of this option, however, uses the MWSS water rate for the cost associated with this backup source, and not the MOC of MWSS.

To lessen the cost of over-extraction of groundwater resources in Metro Manila, the government (through the NWRB) should, therefore, start implementing the Control Area program to regulate pumpage in areas of high threat of saltwater intrusion and eventual depletion. MWSS could also consider jointly operating all high yielding private wells and incorporate them into a distribution system. An additional incentive to control the over-extraction of groundwater would be for MWSS, the alternative source of water, to improve its service so as to provide reliable supply of water with satisfactory pressure for 24 hours per day.

Problems associated with Option 2 indicate it may not be feasible in the immediate future. The on-going and future projects of MWSS may not still meet the increasing water demand from different sectors as a result of population growth and rapid development, thus, an immediate backup source may not be available. Other than fixing broken pipes and meters, going after illegal connections, and assuming the cost of the Umiray-Angat Transbasin Project, the new concessionaires (winners of the recent privatisation of MWSS) have not made public their plans on how else they will meet the water requirements of Metro Manila, Rizal, and some parts of Cavite and Bulacan, and how they will allocate the available water among different competing sectors. Other compounding factors are the increase in areas to be served or placed under MWSS jurisdiction, and the unresolved problem of non-revenue water. Thus, groundwater will remain to be used by those not served or inadequately served by MWSS. And the depletion scenario becomes imminent.

Despite the low charges, and even considering the MOC of MWSS-supplied water, the reliability of the service precludes firms and other consumers from shifting from groundwater to MWSS. The privatisation plan of the government for MWSS hopes to address the problem of quantity rationing and efficiency. Improvement in the water delivery system can help alleviate the problem of groundwater mining. Some recovery of groundwater levels has occurred over the last 10 years in the central part of the NCR. This is attributed to reduced withdrawal due to the availability of additional water from MWSS after the completion of the Manila Water Supply Project II (Haman 1997).

Regulation of pumping rates requires groundwater users to act in ways contrary to self-interest (unless informed of the consequences of their actions) and to internalise the social costs involved. Thus, resources and authority are needed for monitoring and enforcement of prohibited pumping from an unmetered well. All existing wells and pumps have to be inventoried and monitored. This would, however, require additional administrative cost in terms of human resources and acquisition of capital equipment and technology. Considering the stage of groundwater mining, the establishment of a

monitoring network is justified. According to Young (1992), in the groundwater management case, the problem does not appear as difficult as monitoring pollution discharges. He noted that pump meter technology is well-developed and relatively inexpensive.

Another way to verify the volume of water extracted from the wells is through electric power consumption together with verified pump data. In addition, command-and-control policies can be complemented by applying economic instruments, such as imposing charges equal to the estimated marginal opportunity cost corresponding to the use of groundwater. This will make firms internalise social costs, as well as provide a continuous form of incentive for firms to adjust production decisions and utilise new technology and processes to conserve and recycle water, and cut back on pollution discharges, too. The tendency to tamper with the meters could be reduced by requiring the pumper to deposit a monetary bond sufficient to replace non-functioning meters (Young, 1992).

If the on-going and proposed projects of MWSS proceed on schedule, 15 million people out of the projected population of 15.7 million would be served in the year 2015. This scenario assumes new surface water sources as the main source of water, and groundwater withdrawal by MWSS would be reduced to only 280,000 cu.m/d. New wells can still be developed in areas of high piezometric surface in Quezon City, and considering that the safe yield is 560,000 cum/d (presupposing that drilling and pumping of private wells would be controlled). The estimated MPC of using groundwater in this area (Area B) is considerably lower than that in Area A.

Other possible groundwater resources within the area, including the corresponding initial investment costs and problems that may be encountered, have been noted by Haman (1997). One option is to drill wells into the aquifer within Laguna de Bay itself through lake bed infiltration. The lake bottom would serve as a natural filter since the Alluvial sediments and the Laguna/Guadalupe pyroclastic formations, which underlie the lake, would ensure that no artificial treatment would be required other than chlorination. Around 100 wells covering 36 sq. km. (or 3.7% of the lake) would be able to provide about 520,000 cum/d, without exceeding the lake replenishment capacity. Withdrawal of this amount would result, however, in the decrease in the lake water level by 0.2 m and would consequently reduce outflow from the lake during the dry season. The average depth of the lake is 3 m, and land conversion around the lake has increased the siltation of the lake. If the lake is going to be utilised for potable water supply source, then siltation and pollution must be mitigated. Another limitation is the extent of reduction in the outflow from the lake, especially if 900,000 cum/d will be appropriated by NIA for irrigation.

Since new surface water sources will become harder to find and develop, and the financial, social and environmental costs are increasing, developing the well system in the lake is a more acceptable alternative, and would cost around ₱200 million for 100 wells. This system, which can meet the projected deficiency in the MWSS water supply in 2015, is less expensive than developing new surface water sources. Also, it is more environmentally friendly.

Another instrument that should also be considered is a separate charge on wastewater and effluent discharges. Imposing an effluent charge would also serve as incentive for firms to treat wastes before discharge to a receiving water body or to recycle water and minimise both water consumption and total wastewater flows. Water from Laguna de Bay is already being used in certain towns in Rizal, and is being considered for Cavite. Unabated pollution of the lake will increase treatment cost, and may result in the loss of its potential as a water supply source.

It has also been suggested that the regulating agency should publicise the existence and extent of salt water intrusion, and advise industrial water users on appropriate well design and on measures to minimise the use of limited fresh water supplies (National Environmental Protection Council 1987). A related issue is which government agency should collect the user and external charges, which agency should bear the costs of enforcement, and how should the revenues from such water charges be spent. The earmarking of revenues generated from resource and pollution charges should be well defined since the revenue-generating aspect of these charges is not the primary goal.

## 6.0 CONCLUSION

The conjunctive use of groundwater and MWSS is the least-cost alternative for the industrial sector. This would require that withdrawal from the aquifer be regulated to conserve supplies, and that MWSS develop alternative sources and improve the distribution network and water delivery services. For regulation of groundwater extraction, all groundwater users must secure permits, install meters, and pay the corresponding cost (MOC for fully groundwater-supplied users). The regulating agency should start implementing a monitoring network, publicise the existence and extent of salt water intrusion, advise industrial water users on appropriate well design. When planning industrial location, the areas selected should have enough groundwater resources or available infrastructure for the storage of surface water for major water-using industries. Policies must be implemented to encourage industries to move there. Another instrument that should also be considered is a separate charge on wastewater and effluent discharges. Imposing an effluent charge would serve as incentive for firms to treat wastes before discharging to a receiving water body or to recycle water and minimise both water consumption and total wastewater flows. Thus, structural reforms, use of the demand management approach, and proper pricing of the resource, in conjunction with the standard engineering and supply-side approach to the water problem, could lead to a more optimal utilisation and improved allocation of this resource over time.

*He who knows what sweets and virtues  
are in the ground, the plants, the waters,  
the heavens, and how to come at these enchantments  
-- is the rich and royal man.*

- Ralph Waldo Emerson

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